

Traditional Ecological Knowledge and Coastal Landscape Sustainability: Evidence from Fishing Communities of Mandarmani, West Bengal

Rabin Das

Assistant Professor, UG & PG Department of Geography, Bajkul Milani Mahavidyalaya,
Kismat Bajkul, Purba Medinipur, West Bengal, India. dasrabin0@gmail.com

Abstract - The resilience of coastal landscapes is deeply rooted in the dynamic relationship between indigenous knowledge systems and environmental sustainability. This study investigates the Traditional Ecological Knowledge (TEK) held by fishing communities along the Mandarmani Coast in the Purba Medinipur district of West Bengal, India. Accumulated over generations through lived experience, this knowledge encompasses a detailed understanding of tidal cycles, marine biodiversity, seasonal fish migrations, and coastal vegetation. These insights inform traditional fishing techniques, land-use practices, and community-based ecological management. Using a combination of ethnographic fieldwork, participatory rural appraisal, key informant interviews, focus group discussions, and GIS-based landscape analysis, the research documents how indigenous practices such as selective fishing with traditional gear, resource sharing norms, and ritual-based conservation contribute to ecological balance and socio-economic resilience. However, the sustainability of these practices is increasingly threatened by unregulated tourism, coastal erosion, and the impacts of climate variability. The marginalization of local voices and the erosion of traditional knowledge systems pose significant risks to both cultural identity and ecological stability. This paper argues for the recognition of TEK as a valuable and adaptive system, integral to inclusive coastal management and environmental governance. By aligning indigenous wisdom with contemporary sustainability frameworks, the research highlights the role of TEK in fostering adaptive, place-based strategies. It contributes to on-going dialogues on environmental justice, participatory governance, and the co-creation of knowledge for sustainable coastal futures.

Key Words: *Traditional Ecological Knowledge, Fishing Community, Coastal Sustainability, Mandarmani Coast, Environmental Governance*

1. Introduction

Coastal regions across the globe represent dynamic zones of interaction between human communities and natural ecosystems. These fragile yet resource-rich environments have long supported traditional livelihoods, especially fishing, which is deeply embedded in the cultural and ecological fabric of coastal societies. In this context, **Traditional Ecological Knowledge (TEK)** the cumulative body of knowledge, practice, and belief developed by local communities through generations of close interaction with their environment emerges as a vital framework for understanding and sustaining coastal landscapes [4].

The **Mandarmani Coast** in the **Purba Medinipur district of West Bengal, India**, offers a compelling case of such traditional knowledge systems. This littoral stretch, part of the **South Bengal coastal plain**, features a complex fluvio-marine geomorphology with sandy beaches, estuarine creeks, mangrove patches, and dune vegetation. For centuries, local fishing communities here have relied on TEK to interpret tidal cycles, identify fish breeding periods, manage coastal vegetation, and adapt to the monsoonal rhythm of the Bay of Bengal. This indigenous knowledge encompasses more than subsistence it is woven into rituals, seasonal taboos, resource-sharing norms, and community governance practices.

TEK in Mandarmani is manifested through the use of traditional fishing gears (e.g., *ber jal*, *bhasa jal*), community-enforced seasonal fishing restrictions aligned with breeding cycles, and sacred no-fishing zones that function as de facto conservation areas. These practices reflect an eco-centric worldview rooted in respect for the sea, marine biodiversity, and the cyclical nature of coastal ecosystems. Importantly, such systems have historically served as **informal institutions for resource governance**, offering adaptive responses to environmental variability long before the advent of modern regulatory mechanisms [13].

However, this delicate human–environment equilibrium is under increasing threat. The rapid expansion of **coastal tourism**, unregulated resort construction, sand extraction, and changing land-use patterns have triggered widespread ecological degradation. Local communities are being displaced from traditional fishing grounds, sacred sites are being encroached upon, and the knowledge systems that once governed sustainable use are being devalued and eroded. Simultaneously, **climate-induced changes**—including sea-level rise, intensified cyclones, saline water intrusion, and erratic monsoonal behaviour are disrupting marine ecological patterns and affecting the reliability of TEK-based practices [15].

The **marginalization of traditional knowledge holders**, especially elders and artisanal fishers, is exacerbated by the lack of institutional recognition and inclusion of TEK in formal coastal governance. Existing coastal management frameworks often privilege techno-scientific approaches while overlooking the experiential, place-based knowledge of communities that have sustainably inhabited these spaces for generations [1] [18]. This results in governance gaps, community disempowerment, and the erosion of adaptive capacity.

Against this backdrop, the present study aims to **document and analyze the Traditional Ecological Knowledge systems** practiced by the fishing communities of Mandarmani, and to evaluate their role in promoting **ecological sustainability and community resilience**. It also critically examines the socio-economic and environmental pressures undermining these knowledge systems. Through a combination of ethnographic fieldwork, participatory methods, and GIS-based landscape analysis, the study offers a nuanced understanding of the **intersections between TEK, environmental governance, and coastal development**.

Ultimately, this research advocates for the **integration of TEK into participatory and inclusive coastal management**. It emphasizes that indigenous knowledge is not static or backward but **adaptive, dynamic, and complementary to scientific approaches**. Recognizing and institutionalizing TEK offers a pathway toward more **resilient, equitable, and sustainable coastal futures** that center community voices, uphold cultural identities, and protect ecological integrity in a rapidly changing world.

2. Statement of the Problem

Despite the richness of traditional ecological knowledge possessed by fishing communities along the Mandarmani Coast, this valuable repository of environmental wisdom remains under-documented and underappreciated in contemporary policy frameworks. Rapid urbanization, expansion of coastal tourism, and infrastructural development have led to the degradation of coastal habitats and displacement of indigenous communities. These transformations, coupled with climate change and market-driven pressures on marine resources, are eroding the socio-cultural institutions that have historically sustained ecological balance.

Moreover, the increasing reliance on modern technologies and market-centric livelihoods is weakening intergenerational transmission of TEK. As younger generations shift away from traditional occupations and knowledge systems, the risk of cultural loss intensifies. In addition, formal coastal zone management and conservation programs often neglect the perspectives and contributions of local knowledge holders, resulting in alienation and ineffective governance strategies.

The core problem lies in the marginalization of TEK as a viable, adaptive framework for coastal sustainability. There is a pressing need to recognize, document, and integrate these traditional systems within broader sustainability and environmental justice discourses. By doing so, the research aims to bridge the gap between local realities and policy imperatives, and to create space for participatory, bottom-up approaches in managing fragile coastal landscapes.

3. Literature Review

Over the past few decades, **Traditional Ecological Knowledge (TEK)** has emerged as a critical component in discourses on sustainability, particularly in relation to community resilience and environmental stewardship. Defined as a cumulative body of knowledge, practices, and beliefs evolving through generations of close interaction with the environment, TEK is dynamic, adaptive, and culturally embedded [4] [13]. Among coastal and fishing communities, TEK plays a vital role in informing fishing practices, seasonal restrictions, habitat recognition, and local conservation ethics.

Globally, TEK has been widely acknowledged for its contribution to community-based natural resource management, especially where scientific knowledge alone falls short in capturing localized environmental nuances [17] [12]. In coastal regions, such as the Pacific Islands and East Africa, TEK has been effectively integrated into co-management models to improve marine governance and biodiversity conservation.

In the Indian context, **Bay of Bengal coastal communities**, including those in Odisha and West Bengal, possess rich TEK related to tidal cycles, estuarine fisheries, mangrove ecology, and cyclone prediction [21]. The **Sundarbans**, adjacent to the Mandarmani region, has been well documented for its resource-dependent communities that apply TEK in crab collection, fishing calendars, and storm preparedness [8] [14]. However, despite these advancements, there is a **marked absence of empirical research on the TEK systems of the Mandarmani coast**, a region facing rapid socio-ecological transitions.

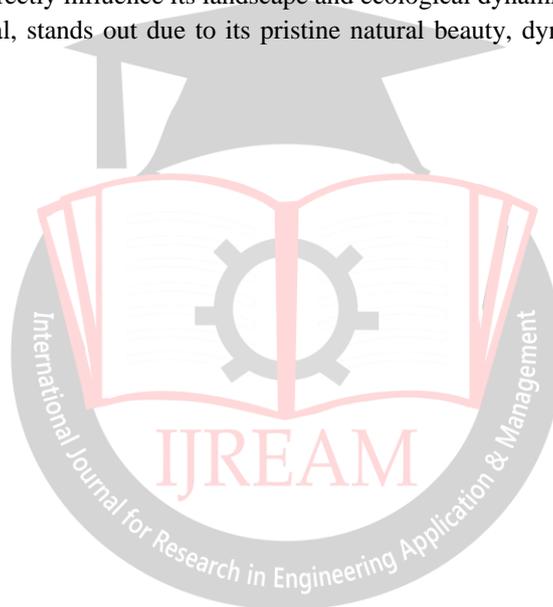
Recent studies have drawn attention to the growing threats to TEK posed by **unregulated coastal tourism, land-use transformation, and infrastructure expansion** [3] [10]. Along the Purba Medinipur coast, tourism-driven development has led to sand dune degradation, habitat fragmentation, and restricted access to traditional fishing grounds, thereby weakening the ecological foundations upon which TEK systems are built. Moreover, **climate change** manifesting as sea-level rise, coastal erosion, and erratic monsoons is further destabilizing the ecological rhythms that communities rely on for traditional practices [15] [7].

While **participatory and co-management approaches** have gained traction globally, their implementation in India's coastal governance remains fragmented. Agrawal and Gibson (1999) and Mukherjee and Chakraborty (2017) argue that institutional frameworks in India often sideline community voices and local knowledge systems in favor of top-down, technocratic planning models. Although policy spaces such as the Coastal Regulation Zone (CRZ) notification and Integrated Coastal Zone Management (ICZM) program provide opportunities for community engagement, the actual incorporation of TEK in these processes is inconsistent and under-theorized [2] [18].

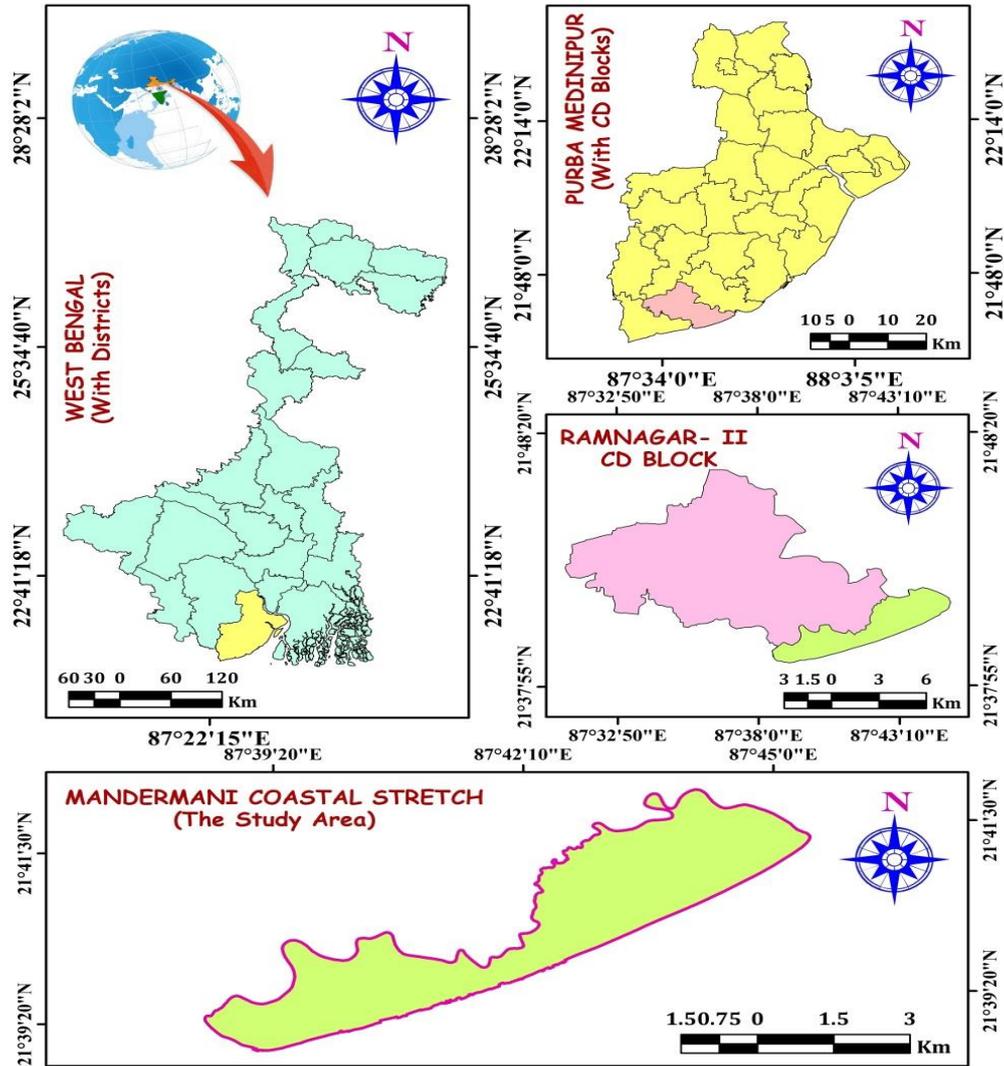
Research Gap: Despite growing recognition of TEK's value, **Mandarmani remains under-represented in scholarly and policy literature**. No comprehensive study has examined how local fishing communities here continue to use, adapt, or lose TEK amid coastal tourism growth, climatic stresses, and changing livelihoods. This study fills that gap by documenting the TEK of Mandarmani's fishing communities and evaluating its relevance to **ecological sustainability, adaptive governance, and community resilience**.

4. The Study Area

The location of a study area encompasses not only its geographical coordinates but also its broader geo-environmental characteristics, which directly or indirectly influence its landscape and ecological dynamics. The Mandarmani coastal stretch, a significant segment of coastal Bengal, stands out due to its pristine natural beauty, dynamic coastal processes, and growing anthropogenic influences.



LOCATION MAP OF THE STUDY AREA

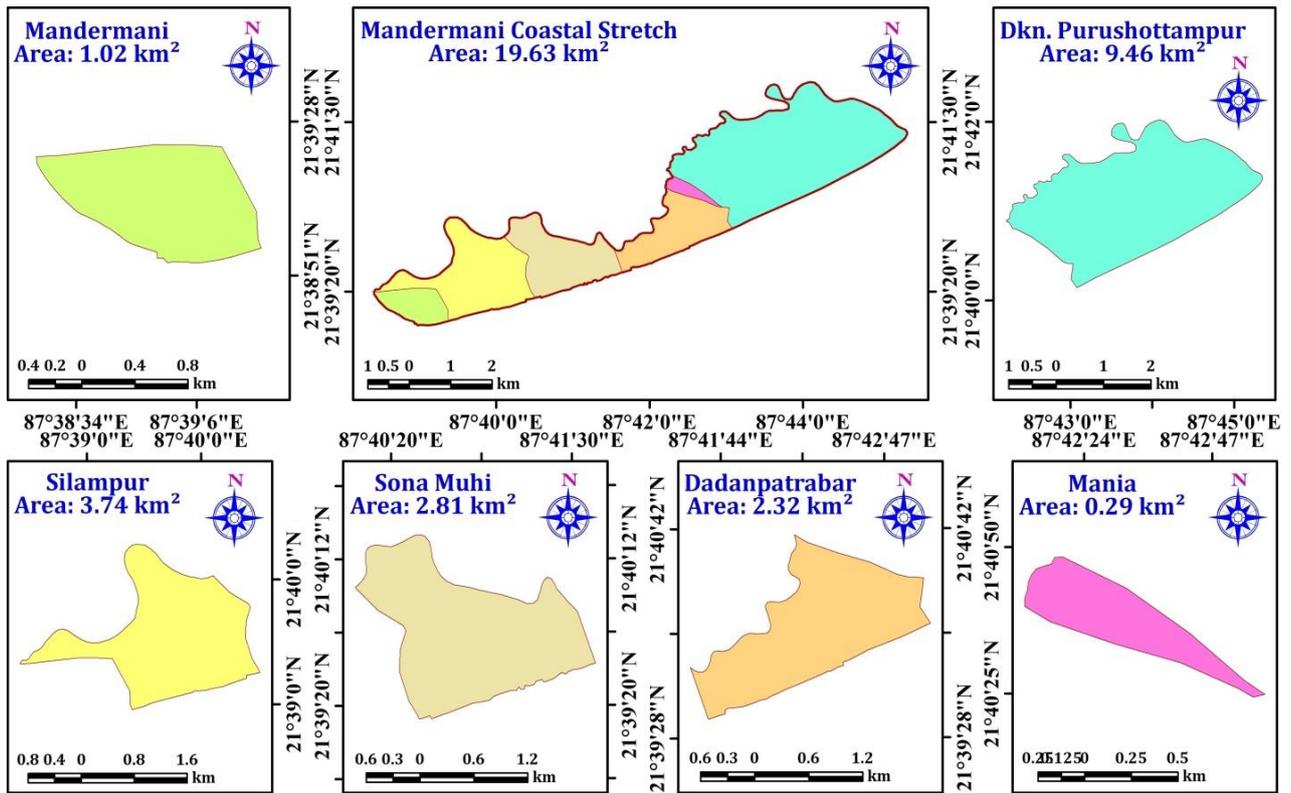


Source: ISGPP, IGISMAP, Thy Maps Guide & Google Earth Imagery, 2024

Figure 1: The Study Area

The study area is located along the Mandarmani coastal belt in the eastern part of Purba Medinipur district, West Bengal, India. Geographically, it extends between $21^{\circ}38'47''\text{N}$ to $21^{\circ}42'25''\text{N}$ latitude and $87^{\circ}38'23''\text{E}$ to $87^{\circ}45'57''\text{E}$ longitude, forming a significant segment of the low-lying, dynamic coastal zone adjacent to the Bay of Bengal. This stretch represents a prominent section of the **Medinipur coast**, known for its environmental sensitivity and socio-economic transformations in recent decades [16].

VILLAGE LAYOUT UNDER MANDARMANI COASTAL STRETCH



Source: ISGPP- II, IGISMAP and Google Earth (Pro) Imagery-2024

Figure 2: Layout of the Villages under Mandarmani Coastal Stretch

Geomorphologically, Mandarmani falls within the **Pichhaboni River sub-basin** of the **South Bengal Basin**, characterized by fluvio-coastal formations shaped by sediment deposition from both riverine and marine systems. The area is bounded by the eastern arm of the **Pichhaboni River** and the western channel of the **Jaldha Khal**, and forms a part of the **Quaternary-Holocene alluvial and fluvio-marine sedimentary complex**, dated to approximately 6,000–8,000 years Before Present (BP) [23] [14]. This geological setting has resulted in a unique coastal landform composed of sandy beaches, tidal flats, backwater creeks, and low dunes.

Ecologically, the Mandarmani coast is a fragile and biodiverse zone marked by **coastal vegetation** such as *Casuarina equisetifolia*, dune grasses, and patches of mangroves in brackish channels. It is flanked by **Soula (Kanthi)** to the east and **Tajpur** to the west, forming a continuous littoral ecosystem that is increasingly threatened by coastal development and tourism [3]. The region also exhibits a rare confluence of natural beauty having sea, sand, and sun making it a focal point of both ecological interest and recreational attraction.

Administratively, the area falls under the **Kalandi Gram Panchayat of Ramnagar-II Community Development Block**, within the **Contai Sub-Division of Purba Medinipur District**. It encompasses six coastal villages with a predominantly rural character and high dependence on marine resources. The rapid expansion of tourism infrastructure, alongside traditional fishing-based livelihoods, poses significant governance challenges in terms of balancing development with conservation. As such, this zone has emerged as a critical site for coastal sustainability research and community-based management efforts [9].

Table 1: Overview of the Study Area, Mandarmani Coastal Stretch under DSDA

Particulars	Mandarmani	Silampur	Sonamuhi	Dadanpatrabar	Mania	Dakshin Purushottampur	Total
Gram Panchayat:	Kalindi Gram Panchayat						
CD Block:	Ramnagr – II CD Block						

Police Station:	Ramnagar PS: MandarmaniCoastal PS						
Sub-division:	Contai Sub-division						
District:	Purba Medinipur District						
State:	West Bengal						
Country:	India						
Pin Code:	721461	721455	721423	721455	721441	721423	-
Geographical Area (Hectare):	170.03	786.36	343.54	266.7	64.35	993.1	2624.08
Population (2011):	507	963	712	1391	6	2394	5973
Households (2011):	97	169	122	301	2	476	1167
Male Population (2011):	258 (50.89)	484 (50.26)	371 (52.11)	728 (52.34)	3 (50)	1255 (52.42)	3099 (51.90)
Female Population (2011):	248 (49.11)	479 (49.74)	341 (47.89)	663 (47.66)	3 (50)	1139 (47.58)	2874 (48.10)
Literacy Rate (2011):	347 (68.44)	609/ (74.91)	525/ (86.78)	1095 (78.72)	6 (100)	1621 (67.71)	4203 70.37
Male Literacy (2011):	186 (72.09)	336/ (81.55)	285/ (89.62)	588 (80.77)	3 (100)	899 (71.63)	2297 (74.12)
Female Literacy (2011):	161 (64.66)	276 (68.08)	240/ (83.62)	507 (76.47)	3 (100)	722 (63.39)	1909 (66.45)
Illiteracy Rate (2011):	160 (31.56)	354 (36.76)	187 (26.26)	296 (21.28)	0	776 (32.41)	1773 (19.64)
Male Illiteracy (2011):	72 (27.91)	148 (30.58)	86 (23.18)	140 (19.23)	0	356 (28.37)	802 (25.88)
Female Illiteracy (2011):	88 (35.48)	206 (43.01)	101 (29.62)	156 (23.53)	0	417 (36.61)	968 (33.69)
Child Population (0-6)/ (2011):	83 (45/38)/ (16.37)	150 (72/ 78)/ (15.58)	107 (53/ 54)/ (15.03)	178 (101/77)/ (12.80)	0	320 (179/ 141)/ (13.37)	883 (450/533)/ (14.78)
Schedule Tribe Population (2011):	3 (2/ 1)	5 (2/3)/ (0.52)	0	88 (53/ 35)/ (6.33)	0	1 (1/ 0)/ (0.04)	97 (58/39)/ (1.62)
Schedule Caste Population (2011):	85 (37/ 48)	64 (36/ 28)/ (6.65)	18 (7/ 11)/ (2.53)	82 (40/ 42)/ (5.90)	0	498 (261/ 237)/ (20.80)	747 (381/366)/ (12.51)
Sex Ratio (2011):	965	990	919	911	1000	908	949
Child (0-6) Sex Ratio (2011):	844	1083	1019	762	0	788	749
Total Workers (2011):	203 (151/ 52)	305 (286/ 19)	186 (181/ 5)	569 (453/ 116)	1	925 (687/ 238)	2189 (1759/430)
Main Workers (2011):	142 (69.95)	152 (49.84)	180 (96.77)	528 (440/ 88)	1	544 (58.81)	1547 (70.67)
Marginal Workers (2011):	61 (22/ 39)/ (30.05)	153 (141/12)/ (50.16)	6 (5/ 1)/ (3.23)	41 (13/ 28)	0	381 (41.19)	642 (29.33)
Agricultural Worker & Cultivator (2011):	51+4=55	15+4=19	34+4=38	118+207=325	0	307+71=378	525+305=830
Working Participation (2011):	1:2.50 (40.04%)	1:3.16 (31.67%)	1:3.83 (26.12%)	1:2.44 (37.96%)	0	1:2.59 (38.64%)	1:2.73 (36.65%)
Nearest Town:	Digha (11km)	Digha (11km)	Contai (21 km)	Contai (22 km)	Contai (20 km)	Contai (19 km)	Digha & Contai

Source: Census of India, 2011

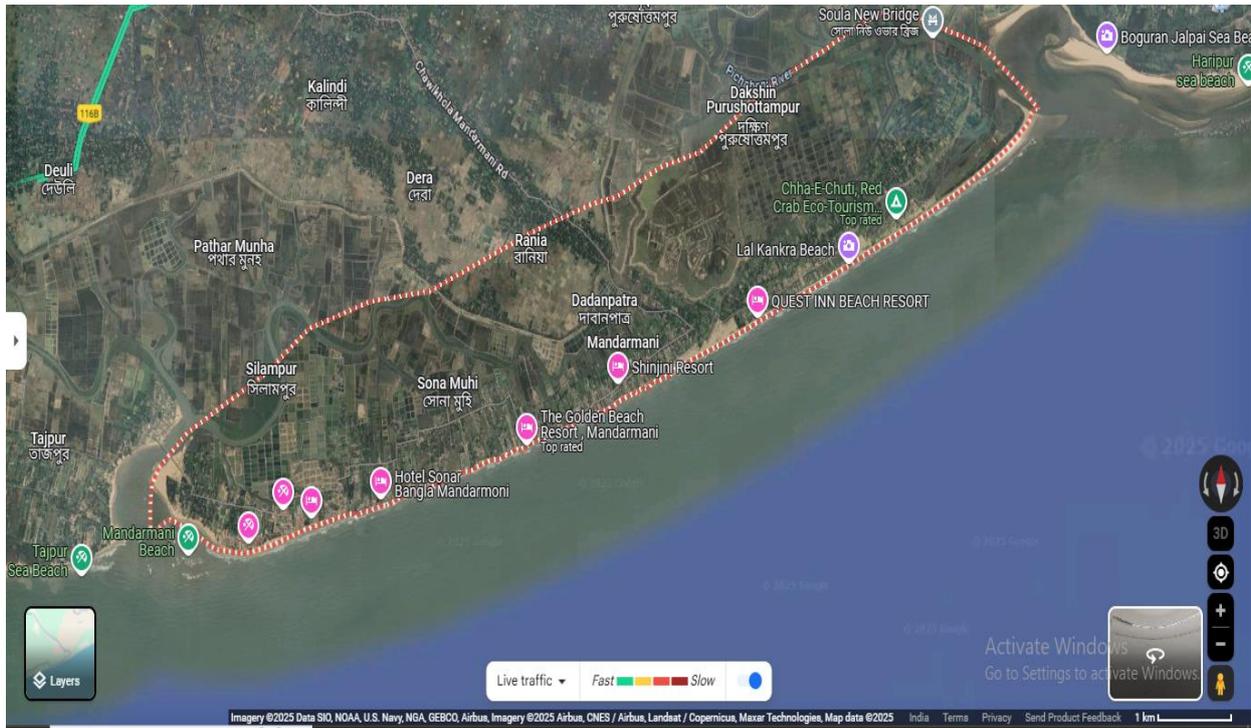


Figure 3: Average Mandarmani Coastal Landscape under Midnapore Coast in West Bengal on Google Satellite Map, 2025

5. Specific Objectives

- To document and analyze the traditional ecological knowledge systems practiced by fishing communities along the Mandarmani Coast.
- To assess the role of TEK in maintaining ecological sustainability and community-based resource governance.
- To examine the challenges posed by coastal tourism, land-use change, and climate variability on TEK systems and livelihoods.
- To propose inclusive, community-centered strategies for integrating TEK into coastal management and policy planning.

6. Methodology

The research adopts a mixed-method approach, combining qualitative ethnographic tools with spatial analysis techniques:

6.1 Study Area: The coastal fishing villages along the Mandarmani coast in the Purba Medinipur district of West Bengal.

6.2 Data Collection Techniques:

- Ethnographic Fieldwork: Prolonged field immersion in selected villages to observe community practices.
- Participatory Rural Appraisal (PRA): Tools like seasonal calendars, transect walks, and resource mapping.
- Key Informant Interviews: Elders, traditional fishers, women fish processors, and community leaders.
- Focus Group Discussions (FGDs): To gather collective perspectives on TEK and emerging challenges.
- GIS and Remote Sensing: Mapping coastal land-use changes, erosion zones, and ecological hotspots.

6.3 Data Analysis:

- Qualitative data is coded thematically using NVivo or Atlas.ti to extract patterns in knowledge, beliefs, and adaptive practices.
- Spatial data is analyzed using QGIS to map land use dynamics, resource zones, and vulnerable areas.
- Triangulation ensures data reliability across multiple sources.

6.4 Ethical Considerations: Informed consent is taken from all participants, ensuring anonymity and respect for cultural sensitivities.

Table 2: Sampled Fishing Respondents as per as per Different Coastal Sections/ Mouzas under Study Area

Surveyed Mouza	Number of Respondents	% of Respondents
Mandarmani Section	36	21.82
Silampur Section	23	13.94

Sonamuhi Section	19	11.52
Dadanpatrabad Section	41	24.85
Dakshin Purushottampur Section	32	19.39
Outside Mandarmani Coastal Stretch	14	8.48
Total	165	100.00

Source: Field Survey, 2025

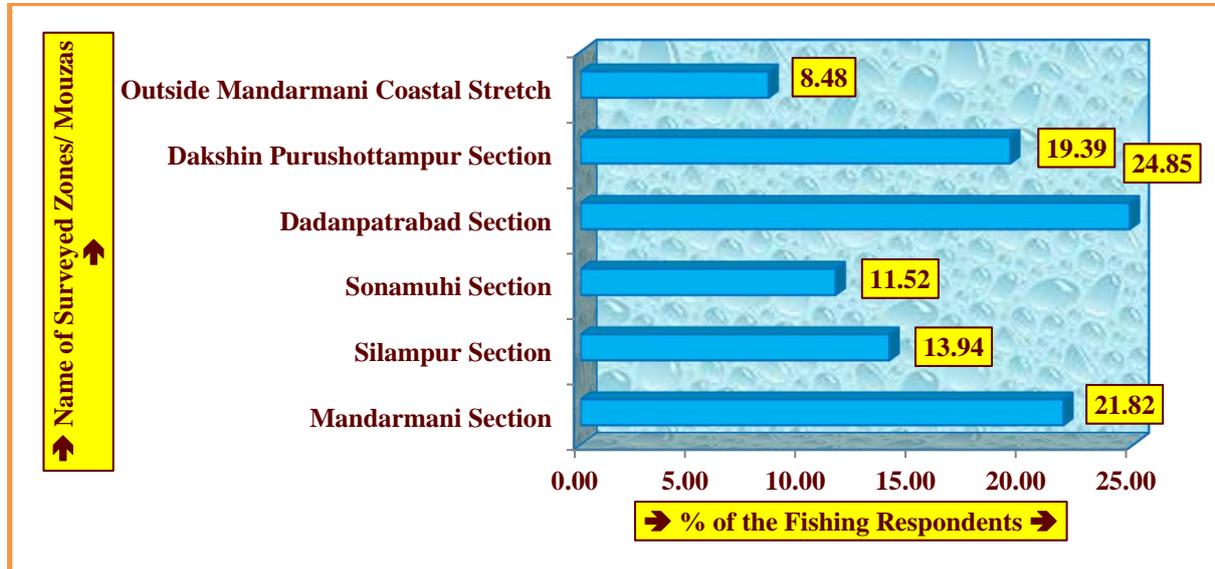


Figure 4: Sampled Fishing Respondents as per as per Different Coastal Sections/ Mouzas under Study Area

7. Result and Discussion

7.1 Documentation and Analysis of Traditional Ecological Knowledge Systems Practiced by Fishing Communities along the Mandarmani Coast

Traditional Ecological Knowledge (TEK) refers to the cumulative body of knowledge, practices, and beliefs developed by indigenous and local communities over generations through direct interaction with their surrounding environment. Along the Mandarmani Coast of West Bengal, fishing communities have nurtured a rich TEK system deeply embedded in their daily life, rituals, and socio-cultural fabric. This knowledge is crucial for sustainable marine resource use, risk mitigation, and environmental adaptation.

7.1.1 Knowledge of Tidal and Lunar Cycles

The fishers of Mandarmani possess an intricate understanding of tidal patterns and lunar phases, which they use to determine optimal fishing times. Their fishing schedules are traditionally synchronized with the **new moon (Amavasya)** and **full moon (Purnima)**, when tidal amplitudes are greatest and fish are more active. This knowledge is not only used to maximize catch but also to avoid dangerous sea conditions, ensuring both efficiency and safety.

- **Tidal literacy** enables fishers to predict water level changes, influencing where nets are placed or which estuarine creeks are accessed.
- Fisher folk avoid venturing out during "bad tides" or stormy lunar combinations, indicating deep-rooted disaster risk awareness embedded in TEK.

7.1.2 Seasonal Fish Migration and Breeding Knowledge

Local fishers have developed an intimate awareness of the **seasonal availability and migratory behavior of fish species** such as hilsa (*Tenualosa ilisha*), pomfret, prawns, and crabs. This TEK informs their fishing gear choices and timing:

- For example, **prawn seed collection** occurs primarily between March and June, coinciding with natural spawning seasons.
- **Net size and type** are adjusted to minimize juvenile fish capture, reflecting a form of **traditional conservation ethics**.

Such practices demonstrate ecological foresight and an understanding of **species life cycles**, which modern fisheries often overlook.

7.1.3 Use of Traditional Fishing Gear and Techniques

Traditional gears like "ber jal" (drag nets), "tana jal" (pull nets), and "bhasa jal" (floating nets) are still in use. These are locally made from organic or semi-organic materials and are species and habitat-specific. They are often less invasive than industrial trawling, thereby preserving **benthic marine habitats**.

- **Selective fishing** ensures that only target species are captured, reducing bycatch.
- Handcrafted canoes and catamarans are used in shallow waters, which prevent deep-sea disturbances and promote localized resource use.

These methods contribute to **low ecological footprint fishing**.

7.1.4 Coastal Vegetation and Mangrove Use

Communities also maintain TEK related to coastal vegetation, particularly **mangrove plants** (e.g., *Avicennia*, *Rhizophora*), which they recognize as storm barriers and fish nurseries. Although not part of formal afforestation programs, villagers plant mangroves along erosion-prone banks and are aware of their **soil-binding properties**.

- Mangrove leaves are used for fish smoking and preservation.
- Roots and bark have traditional medicinal and ritual uses, demonstrating an **eco-spiritual connection** with the landscape.

7.1.5 Ritual-based Conservation and Socio-cultural Taboos

Several fishing-related activities are governed by **rituals, taboos, and seasonal bans**, which indirectly help in biodiversity conservation:

- **Seasonal fishing bans** during monsoon are observed voluntarily, aligning with fish breeding periods, even before such bans were enforced by the state.
- Sacred spaces (e.g., "Jal Devata/ Maa Ganga" shrines) and customary no-fishing zones reflect an indigenous **marine zoning system** rooted in respect for natural forces.

Such taboos serve as **cultural checks** on overexploitation, creating social consensus on sustainable resource use.

7.1.6 Community-Based Resource Sharing

TEK systems emphasize **collective access and informal governance** over marine resources. In many Mandarmani villages, fish landing sites, gear repairs, and fishing expeditions are carried out communally:

- **Conflict resolution mechanisms** over fishing grounds are managed locally, often without state interference.
- **Reciprocity** in sharing catches during lean seasons reflects a **resilience-based economy**, supported by social capital rather than market dependence.

This collective ethic provides a buffer against resource inequality and fosters long-term sustainability.

The traditional ecological knowledge systems of Mandarmani's fishing communities are multifaceted, encompassing ecological observations, technological adaptations, cultural norms, and socio-economic practices. These systems demonstrate a **functional environmentalism** that predates formal conservation science. Importantly, TEK has allowed these communities to sustain livelihoods while maintaining ecological integrity in a dynamic and vulnerable coastal ecosystem.

However, the erosion of these knowledge systems due to modernization, reduced intergenerational transfer, youth migration, and external developmental pressures poses serious risks. The **integration of TEK into formal coastal governance**, supported by education, documentation, and legal recognition, is urgently needed to ensure both cultural continuity and environmental sustainability.

Table 3: Traditional Ecological Knowledge Systems Practiced by Fishing Communities along the Mandarmani Coast

Different Traditional Ecological Knowledge Systems	Number of Respondents				% of Respondents			
	Fully Knowledgeable	Partially Knowledgeable	Not Knowledgeable	Total	Fully Knowledgeable	Partially Knowledgeable	Not Knowledgeable	Total
Knowledge of Tidal and Lunar Cycles	156	9	0	165	94.55	5.45	0.00	100
Seasonal Fish Migration and Breeding Knowledge	113	29	23	165	68.48	17.58	13.94	100
Knowledge regarding Use of Traditional Fishing Gear and Techniques	81	45	39	165	49.09	27.27	23.64	100
Knowledge of Coastal Vegetation and Mangrove Use	96	38	31	165	58.18	23.03	18.79	100
Ritual-based Conservation and Socio-cultural Taboos	129	19	17	165	78.18	11.52	10.30	100

Community-Based Resource Sharing	96	47	22	165	58.18	28.48	13.33	100
Average	112	31	22	165	67.78	18.89	13.33	100

Source: Field Survey, 2024

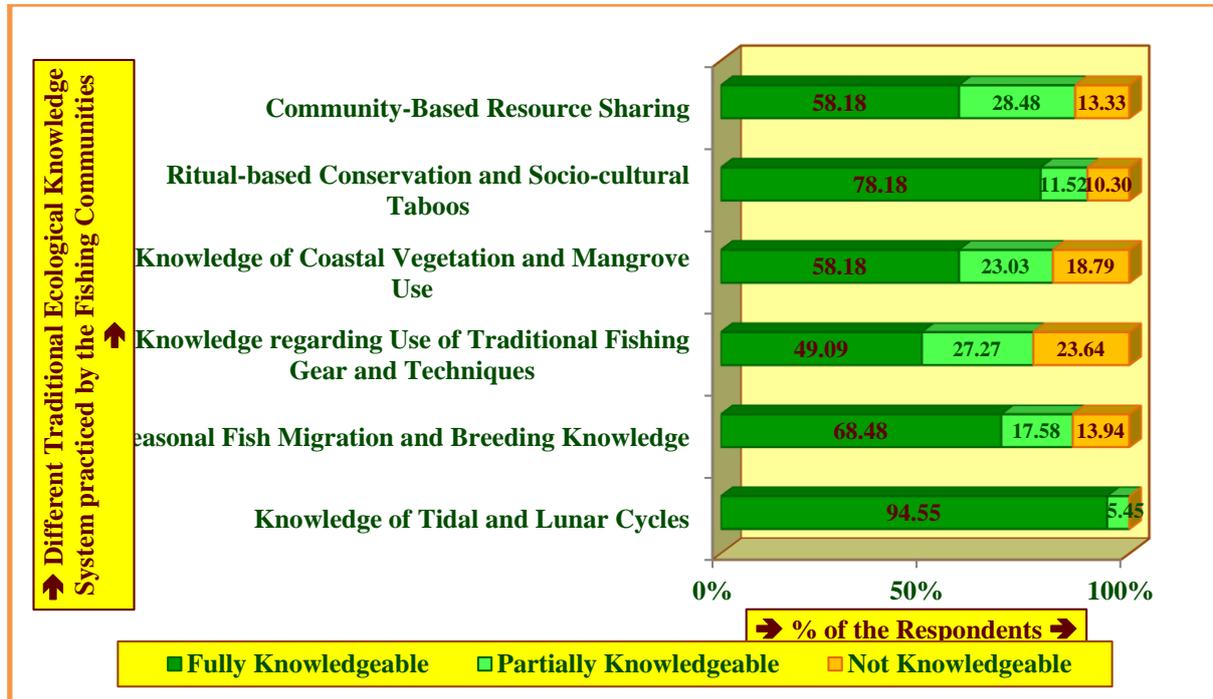


Figure 5: Traditional Ecological Knowledge Systems Practiced by Fishing Communities along the Mandarmani Coast

7.2 Assessment of the Role of Traditional Ecological Knowledge (TEK) in Maintaining Ecological Sustainability and Community-Based Resource Governance

Traditional Ecological Knowledge (TEK) functions as a cornerstone of ecological sustainability and decentralized governance in many indigenous and coastal communities. Along the Mandarmani Coast of West Bengal, TEK plays a vital role not only in ensuring responsible resource use but also in fostering social cohesion, risk reduction, and adaptive management. Rooted in lived experience and transmitted orally through generations, TEK acts as both an environmental and institutional asset that contributes to resilient socio-ecological systems.

7.2.1 TEK as an Indigenous Framework for Sustainable Resource Use

Fishing communities along the Mandarmani Coast follow ecological principles that are embedded in their TEK systems, including species-specific fishing, seasonal bans, and localized habitat understanding. These practices demonstrate **de facto conservation strategies** long before formal scientific management or regulatory frameworks were introduced.

- Fishers apply **seasonal calendars** to avoid overexploitation during breeding periods. This aligns with scientific concepts of fish stock regeneration and sustainable yield.
- Traditional gear (e.g., “bhasa jal”, “ber jal”) is designed for **selective fishing**, reducing by catch and minimizing damage to marine and benthic habitats.

Through such low-impact techniques, TEK practitioners actively **contribute to biodiversity conservation**, maintenance of ecosystem services, and long-term resource sustainability.

7.2.2 Risk Reduction and Climate Adaptation

TEK contributes significantly to ecological risk management and climate change adaptation:

- Knowledge of **monsoonal cycles, tidal surges, and storm patterns** helps communities prepare for natural disasters, reinforcing community resilience.
- Mangrove planting and traditional dune stabilization techniques demonstrate **ecosystem-based adaptation**, reducing the vulnerability of coastlines to erosion and saline intrusion.

Thus, TEK plays a central role in developing **nature-based solutions (NbS)**, enhancing both ecological and socio-economic resilience.

7.2.3 Community-Based Resource Governance

TEK forms the ethical and functional basis of **community-based resource management (CBRM)** along the Mandarmani coast. These informal governance systems are characterized by collective decision-making, equitable access, and culturally embedded rules:

- **Local norms and taboos** regulate where and when fishing can occur. For example, certain estuarine zones are considered sacred or reserved, functioning as **informal marine protected areas (MPAs)**.
- **Rotational harvesting systems** where families or groups take turns accessing prime fishing areas ensure fairness and avoid overharvesting.

These systems exemplify **bottom-up governance**, driven by mutual trust, customary laws, and consensus rather than state-imposed regulations.

7.2.4 Social Capital and Ecological Stewardship

TEK not only manages ecosystems but also reinforces **community identity, moral values, and cooperation** all essential for participatory governance.

- Rituals, festivals, and oral histories related to the sea and fishing practices foster a **collective environmental ethic**.
- Knowledge exchange between elders and youth maintains **intergenerational continuity**, sustaining long-term adaptive capacity.

Such shared values enhance **compliance** with ecological norms, making community enforcement more effective than external policing.

7.2.5 TEK vs. Formal Institutions: The Governance Gap

Despite its strengths, TEK is often excluded from formal coastal zone management (CZM) policies, which are largely technocratic and top-down. This disconnect results in:

- **Regulatory overlaps**, where state-imposed fishing bans may not align with traditional calendars.
- **Conflicts** over land use and marine access, especially with the expansion of tourism, aquaculture, and port infrastructure.

Recognizing and integrating TEK into official governance mechanisms could bridge this gap, leading to **hybrid governance models** that combine local insight with scientific data and institutional support.

7.2.6 Policy Relevance and Future Pathways

For TEK to contribute meaningfully to sustainable coastal development, it must be:

- **Recognized legally**, with protections for intellectual and cultural rights.
- **Incorporated into disaster management plans**, climate action strategies, and biodiversity conservation programs.
- **Institutionalized** through platforms for participatory planning, co-management councils, and knowledge documentation centers.

Empowering local communities through **capacity-building and decentralized governance** rooted in TEK can help achieve multiple Sustainable Development Goals (SDGs), particularly SDG 14 (Life Below Water), SDG 13 (Climate Action), and SDG 11 (Sustainable Communities).

Traditional Ecological Knowledge is both an ecological compass and a governance tool for the fishing communities of the Mandarmani Coast. Its role in sustaining marine ecosystems, promoting equitable access, and enabling climate resilience is indispensable. Rather than treating TEK as anecdotal or obsolete, it must be embraced as a **living, adaptive, and scientifically valuable knowledge system**. Embedding TEK into mainstream coastal governance will not only protect local livelihoods and biodiversity but also pave the way for more just and sustainable coastal futures.

7.3 Assessment of Traditional Ecological Knowledge Index (TEKI) for Mandarmani Coastal Fishing and Allied Livelihood

Here is to quantify the level of traditional ecological knowledge (TEK) practiced and preserved by households or villages engaged in coastal fishing and related livelihoods in the Mandarmani region.

Table 4: Theoretical Framework for TEK Indicator Rating

Dimension	TEK Indicator	Scoring Range
1. Knowledge of Marine Ecology	Knowledge of fish breeding/migration seasons	0 = No, 1 = Partial, 2 = Full
	Understanding of tidal/lunar cycles	0 = No, 1 = Yes
	Knowledge of mangrove uses (ecological/medicinal)	0 = No, 1 = Yes
2. Fishing Practices	Use of traditional fishing gear (e.g., bhasa jal, ber jal)	0 = No, 1 = Yes
	Participation in seasonal fishing bans or rituals	0 = No, 1 = Yes
	Avoidance of juvenile catch (selectivity)	0 = No, 1 = Partially, 2 = Yes

3. Resource Governance	Participation in community-based decision-making	0 = No, 1 = Yes
	Observance of sacred zones/ no-fishing zones	0 = No, 1 = Yes
4. Knowledge Transmission	TEK transferred to children/youth in household	0 = No, 1 = Partially, 2 = Fully
	Engagement in local storytelling or rituals involving ecological themes	0 = No, 1 = Yes
5. Adaptation & Resilience	Knowledge of cyclone prediction (traditional indicators)	0 = No, 1 = Yes
	Use of traditional strategies for coping with bad weather/poor catch seasons	0 = No, 1 = Yes

Source: Author's Literature Review & Theoretical Analysis, 2025

Scoring and Normalization

1. **Total Raw Score per Household** = Sum of scores across all indicators

- **Maximum Score** = 18 (example: if all best scores achieved)
- **Minimum Score** = 0

2. **Normalized TEKI Value** for each household:

- $TEKI_i = \frac{Raw\ Score - Min\ Score}{Max\ Score - Min\ Score}$
- This scales values between **0 (low TEK)** and **1 (high TEK)**

Table 6: TEKI Classification

TEKI Range	TEK Level Classification
0.75 – 1.00	High Traditional Ecological Knowledge
0.50 – 0.74	Moderate TEK
0.25 – 0.49	Low TEK
0.00 – 0.24	Very Low TEK

Source: Author's Theoretical Analysis from Literature Survey, 2025

Table 7: Assessment of Traditional Ecological Knowledge Index (TEKI) for Different Villages along Mandarmani Coastal Landscape

Name of Villages	Knowledge of Marine Ecology			Fishing Practices			Resource Governance		Knowledge Transmission		Adaptation & Resilience		Raw Score	Traditional Ecological Knowledge Index (TEKI) (0-1)
	Fish Breeding Season Knowledge (0-2)	Tidal/ lunar Cycle Knowledge (0-1)	Mangrove Knowledge (0-1)	Use of Traditional Fishing Gear (0-1)	Participating in Seasonal Fishing Rituals (0-1)	Juvenile Catch Avoidance (0-2)	Community-based Resource Sharing Involvement/ Participation (0-1)	Sacred No-fishing Zones Observed (0-1)	TEK Transfer to Children (0-2)	Ecological Ritual Engagement (0-1)	Traditional Cyclone Prediction Knowledge (0-1)	Use of Coping Strategies during Lean Periods (0-1)		
Mandarmani	2	1	1	1	1	1	1	1	1	1	1	1	13	0.92857
Silampur	2	1	1	1	0	0	0	0	0	0	1	0	6	0.42857
Sonamuhi	1	1	0	0	0	0	0	0	0	0	0	0	2	0.14286
Dadanpatrabad	1	1	0	1	1	1	1	1	0	0	1	1	10	0.71429
Dakshin Purushottampur	2	1	1	1	1	2	1	1	1	1	1	1	14	1.00000
Average	1.6	1	0.6	0.8	0.6	1	0.6	0.6	0.6	0.6	0.8	0.6	9.4	0.67143

Source: Combining Qualitative Ethnographic Field Survey & Data Analysis, 2025

From the above TEKI assessment, following applications should be taken into consideration as the plan, policy and programme for enhancing the fishing livelihood and coastal resilience:

- **Policy insight** for identifying high-TEK villages for community-based conservation programs.
- **Risk targeting** for focussing climate adaptation plans in low-TEK zones.
- **Correlation analysis** for examining the relationships between TEKI and household income, land tenure, or tourism proximity.
- **Monitoring** for using TEKI as a baseline for longitudinal studies (e.g., TEK erosion or revival over 5–10 years).

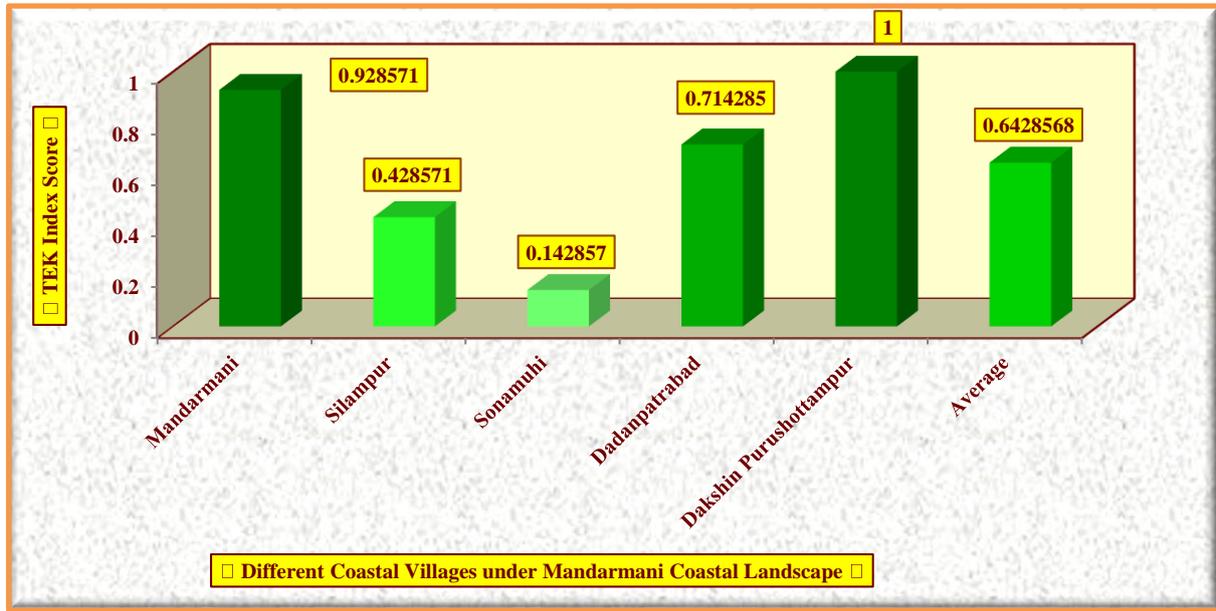


Figure 6: Assessment of Traditional Ecological Knowledge Index (TEKI) for Different Villages along Mandarmani Coastal Landscape

7.4 Strategic SWOT Assessment regarding Traditional Ecological Knowledge (TEK) and Coastal Governance for Fishing Livelihood in the Study Area

7.4.1 SWOT Assessment regarding TEK and Coastal Governance in Mandarmani

Strengths (S)	Weaknesses (W)
S1. Deep-rooted traditional ecological knowledge across generations	W1. Lack of formal recognition of TEK in coastal governance frameworks
S2. Community-based conservation norms and seasonal fishing bans already practiced	W2. Decline in TEK transfer among youth due to livelihood diversification
S3. Indigenous coping mechanisms for climate events (e.g., tidal predictions)	W3. Limited documentation or institutional validation of TEK systems
S4. Social cohesion in fishing communities fosters collective action	W4. Inadequate access to modern training or TEK-sensitized education programs
Opportunities (O)	Threats (T)
O1. Participatory coastal planning under CRZ/ ICZM frameworks	T1. Rapid expansion of unregulated coastal tourism displacing traditional systems
O2. Government emphasis on blue economy and community-based conservation (e.g., CCAs)	T2. Climate variability disrupting ecological rhythms underlying TEK
O3. Technological tools (GIS, mobile apps) to document and visualize TEK	T3. Youth migration and erosion of intergenerational knowledge continuity
O4. Scope for ecotourism based on traditional knowledge and marine rituals	T4. Market-driven aquaculture threatening local biodiversity and access rights

Source: Combining Qualitative Ethnographic Field Survey & Data Analysis, 2025

7.4.2 Quantitative Strategic Planning Matrix (QSPM)

This QSPM helps **objectively prioritize interventions** by assigning relative weights to SWOT factors and rating how well each strategy addresses them.

Code	Strategy Description
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A1	Integrate TEK into formal coastal planning through participatory village-level governance institutions
A2	Develop TEK-based community eco-tourism (cultural fishing trails, festivals, heritage rituals)
A3	Launch youth-targeted TEK revival programs (school curricula, storytelling, skill workshops)
A4	Establish TEK digital knowledge bank (mobile + GIS-based documentation of traditional fishing zones, etc.)

Source: Combining Qualitative Ethnographic Field Survey & Data Analysis, 2025

SWOT Dimensions	SWOT Factors	Weight	A1 (TEK-Policy)	A2 (TEK-Ecotourism)	A3 (Youth-Revival)	A4 (Digital-TEK Map)
Strength (S)	S1. Deep-rooted TEK	0.10	4	3	2	3
	S2. Community conservation norms	0.08	4	4	2	2
Weakness (W)	W1. Lack of TEK recognition	0.09	4	2	1	3
	W2. TEK erosion among youth	0.07	2	2	4	3
Opportunity (O)	O1. Participatory governance	0.10	4	3	3	3
	O3. GIS/mTech support	0.08	2	3	2	4
Threat (T)	T1. Tourism threat	0.09	4	4	2	2
	T2. Climate variability	0.07	3	2	2	3
	T3. Youth migration	0.06	2	2	4	2
Total Weighted Score		1.00	3.36	2.97	2.46	2.85

N.B.: 1 = Not Effective, 4 = Highly Effective

Source: Combining Qualitative Ethnographic Field Survey & Data Analysis, 2025

7.4.3 Strategic Recommendation Based on QSPM

Strategy	Total Score	Rank	Recommendation
A1. TEK-Policy Integration	3.36	1st	Top priority: Embed TEK in coastal governance
A2. TEK-based Ecotourism	2.97	2nd	Promote as income diversification strategy
A4. Digital TEK Mapping	2.85	3rd	Use GIS/mTech to preserve and disseminate TEK
A3. Youth TEK Revitalization	2.46	4th	Integrate TEK into education & skill programs

Source: Combining Qualitative Ethnographic Field Survey & Data Analysis, 2025

From the above analysis the estimated QSPM clearly shows that the **most effective intervention** is to:

- **Institutionalize TEK through participatory coastal governance mechanisms** such as village-level TEK councils and inclusion in CZMPs, supported by community-based decision-making.
- Other complementary actions like **eco-tourism, digital TEK mapping, and youth engagement** can reinforce the TEK system and ensure its adaptive sustainability.

7.5 Challenges Posed by Coastal Tourism, Land-Use Change, and Climate Variability on Traditional Ecological Knowledge (TEK) Systems and Livelihoods in the Mandarmani Coast

The resilience and continuity of Traditional Ecological Knowledge (TEK) systems among coastal fishing communities are increasingly under threat due to rapid socio-environmental transformations. Along the Mandarmani coast of West Bengal an area historically rooted in artisanal fishing, ecological adaptation, and indigenous knowledge the unchecked rise of mass tourism, land-use conversion, and climate-induced disruptions have converged to weaken TEK-based livelihoods and governance mechanisms. These challenges are multidimensional, affecting not only the ecological foundation of TEK but also its social, cultural, and economic reproduction.

7.5.1 Displacement and Disruption from Coastal Tourism

The exponential growth of tourism infrastructure like hotels, resorts, amusement zones, and service roads has led to the **encroachment of coastal commons**, displacing traditional fishing zones and obstructing access to the sea.

- **Loss of access to jetties, landing sites, and drying yards** restricts daily fishing operations and interrupts associated knowledge practices such as net drying, fish sorting, and post-harvest rituals.
- Seasonal influxes of tourists also generate **pollution (plastic waste, sewage), noise, and behavioral conflicts**, degrading the sensitive coastal ecology and disrupting the spiritual and cultural settings in which TEK is traditionally embedded.

As a result, **youth are shifting away from fishing** toward low-wage jobs in tourism (e.g., waiters, drivers), weakening intergenerational knowledge transfer and eroding traditional livelihoods.

7.5.2 Land-Use Change and Habitat Fragmentation

Rapid **conversion of coastal land for urban development, aquaculture farms, and tourism infrastructure** is leading to the degradation of ecologically critical habitats such as mangroves, dunes, and estuarine creeks.

- These habitats are central to TEK, as they serve as **breeding and nursery grounds for fish**, sources of medicinal plants, and buffers against tidal surges.
- Land privatization and real estate speculation are replacing common property regimes with **individual tenure systems**, weakening communal stewardship and disrupting **community-based resource governance** systems grounded in TEK.

Fragmentation of coastal ecosystems reduces the viability of traditional fishing practices and undermines the ecological base that TEK relies upon for sustainable resource use.

7.5.3 Climate Variability and Environmental Uncertainty

Climate change is further compounding the vulnerability of TEK systems by introducing **unpredictability into long-standing ecological rhythms**.

- **Erratic monsoons, shifting tidal patterns, and rising sea levels** are altering fish migration and spawning seasons, rendering traditional seasonal calendars less reliable.
- **Increased frequency of cyclones (e.g., Amphan, Yaas)** causes infrastructural damage to boats, nets, and coastal shelters, eroding both material resources and community resilience.
- Saline intrusion into agricultural and freshwater zones is forcing fishers to migrate or diversify into unfamiliar occupations, disrupting traditional knowledge cycles.

As TEK is rooted in long-term environmental observations, such rapid changes create **epistemological dissonance**, wherein older knowledge systems fail to fully explain or address new phenomena.

7.5.4 Socio-Cultural Marginalization and Policy Neglect

Modern coastal management policies in India often prioritize economic growth and conservation without adequately consulting or involving local communities. This leads to:

- **Exclusion of TEK holders from decision-making platforms**, environmental impact assessments, and zoning exercises.
- Institutional promotion of scientific knowledge as superior, contributing to the **devaluation of TEK** in both formal education and policy.
- Weak or absent legal protection for customary rights and communal fishing grounds, further marginalizing TEK-based resource users.

Such structural neglect discourages community participation and promotes a sense of alienation, leading to **knowledge attrition and identity loss**.

The interlinked forces of tourism, land-use transformation, and climate change are not only ecological threats but also sociocultural disruptions that **destabilize the very foundations of TEK systems** in the Mandarmani coastal region. These changes challenge the **adaptive capacity, spiritual continuity, and governance relevance** of indigenous knowledge frameworks. Without urgent policy interventions, there is a high risk that TEK will become obsolete reduced to folklore rather than a living, evolving system of sustainability.

- To address these challenges, there is a pressing need for:
- **Participatory coastal planning** that integrates TEK as a legitimate knowledge system.
- **Recognition of customary marine tenure and access rights**.
- **Climate-resilient livelihood diversification** that retains cultural and ecological knowledge.
- **Youth sensitization and intergenerational knowledge programs** to revitalize TEK transmission.

7.6 Proposing Inclusive, Community-Centered Strategies for Integrating TEK into Coastal Management and Policy Planning

The integration of **Traditional Ecological Knowledge (TEK)** into formal coastal management frameworks is both a necessity and an opportunity for achieving sustainable, equitable, and adaptive environmental governance [5]. On the **Mandarmani Coast** of West Bengal, where fishing communities possess intricate ecological insights and centuries-old stewardship traditions, inclusive strategies must move beyond tokenism to create genuine partnerships between communities and institutions [2] [12]. Below are community-centered, actionable strategies that can strengthen TEK systems and embed them meaningfully into policy processes.

7.6.1 Participatory Coastal Governance Platforms

Establish **multi-stakeholder governance councils** at the village, panchayat, and district levels that include traditional fishers, women processors, NGOs, scientists, and tourism-sector representatives. Such platforms echo the co-management models proven effective in other contexts [17] and can:

- Conduct participatory resource assessments
- Recommend seasonal bans informed by both scientific and traditional calendars
- Mediate land-use conflicts and promote ecological zoning

These institutions would uphold the principles of **environmental justice, decentralization, and polycentric governance** [19], empowering community voices in planning.

7.6.2 Legal and Institutional Recognition of TEK

Policy reforms must formally recognize TEK as a legitimate body of environmental knowledge [1] [18]. For example:

- The **Coastal Regulation Zone (CRZ)** and **Coastal Zone Management Plans (CZMPs)** should incorporate TEK-based mapping and traditional resource use zones.
- Promote **Community Conserved Areas (CCAs)** that legally acknowledge the stewardship of local communities over critical habitats.

This approach strengthens **tenure security**, supports rights-based conservation, and integrates TEK into **Environmental Impact Assessments (EIAs)** and climate adaptation strategies [6].

7.6.3 Documentation and Transmission of TEK

Community-led documentation can preserve and revitalize TEK through:

- Ethnographic mapping of fishing zones and sacred ecological sites
- Oral history recordings of rituals, weather prediction, and traditional gear usage
- Digital repositories and local language databases

Introducing **TEK-based educational content** in schools and youth programs ensures intergenerational continuity and cultural revitalization [22].

7.6.4 TEK-Informed Disaster Risk Reduction and Climate Adaptation

TEK offers actionable knowledge for **disaster preparedness and resilience**:

- Integrate traditional storm indicators and tidal literacy into state disaster management plans [7]
- Promote ecosystem-based adaptation using **mangrove barriers, dune vegetation**, and local conservation rituals
- Establish **community climate monitors** combining TEK with scientific observation

This aligns with global best practices in **hybrid adaptation approaches** and locally-led resilience models [11].

7.6.5 Sustainable Livelihood Diversification with TEK Integration

Livelihood programs should harness TEK in:

- **Eco-cultural tourism**, showcasing artisanal fishing and community rituals
- **Organic aquaculture**, using local species knowledge and low-impact methods
- Traditional fish preservation and value-added product development

When supported by **microcredit, cooperatives, and blue economy platforms**, these models can foster both ecological and economic resilience [5].

7.6.6 Institutional Collaboration and Knowledge Co-Production

Encourage **collaborative research** between universities, NGOs, and community knowledge holders:

- Co-develop tools like **participatory GIS**, seasonal resource calendars, and TEK-environment indicators
- Organize **joint training workshops and field labs**

This facilitates **knowledge co-production** where TEK and science converge to generate actionable insights for **marine spatial planning and coastal governance** [20].

For TEK to thrive and contribute meaningfully to sustainable coastal futures, it must be embedded within governance structures that are inclusive, adaptive, and respectful of local cultural landscapes. The strategies proposed here ranging from participatory councils and legal recognition to youth education and co-produced research form a comprehensive roadmap for **community-centered coastal management**. Integrating TEK is not simply a matter of inclusion, but a **pathway toward ecological wisdom, cultural resilience, and democratic environmental planning** in the face of mounting coastal challenges.

8. Conclusion

The Mandarmani Coast of West Bengal stands as a vital socio-ecological system where traditional fishing communities have long coexisted with a dynamic coastal environment through the guidance of Traditional Ecological Knowledge (TEK). This research has shown that TEK is not merely a historical artifact but a living, adaptive knowledge system that supports ecological sustainability, resource governance, and cultural identity. From tidal forecasting and selective fishing to sacred marine zones and community-based conservation, TEK represents an invaluable toolkit for sustainable coastal living.

However, this knowledge system is under increasing threat from unregulated tourism, land-use transformation, and climate variability, which disrupt both the ecological rhythms and the socio-cultural mechanisms that sustain TEK. These pressures risk severing the intergenerational links that keep TEK alive, while simultaneously undermining the ecological balance that it helps maintain.

To address these challenges, it is essential to reposition TEK at the core of coastal policy and planning. Inclusive, community-centered strategies grounded in participatory governance, legal recognition, youth engagement, and knowledge co-production can transform TEK from a marginalized tradition into a central pillar of sustainability science and practice.

The sustainable message emerging from this study is clear that **safeguarding traditional knowledge is not just about preserving culture it is about protecting ecosystems, enhancing resilience, and empowering communities to become stewards of their own futures.**

As India navigates the complexities of coastal development under climate stress, integrating the wisdom of local communities with modern frameworks offers the most hopeful path forward. A resilient and sustainable Mandarmani Coast must therefore be one where **traditional ecological knowledge and modern governance walk hand in hand toward justice, sustainability, and shared prosperity.**

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